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# The Molybdenum Content of West Virginia Soils

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## Introduction

MOLYBDENUM is one of the latest elements to be classified as essential to normal plant growth. When insufficient amounts are available in the soil, plants may suffer from molybdenum deficiency. Molybdenum also is important from an agricultural standpoint in that soils containing excessive available molybdenum may produce forage that, under certain conditions, may be toxic when consumed by grazing animals (2).

The extent to which molybdenum deficiencies occur in the United States has not been fully established. Recent reports (8) indicate that field deficiencies have occurred in at least thirteen states.

In West Virginia, Fairchild, Kemper, and Marvel[1] noted the occurrence of molybdenum deficiency in certain varieties of cauliflower grown in the Canaan Valley of Tucker County. No report has been made of molybdenum deficiency in any other part of the State.

There have been no reports of molybdenum toxicity in the humid areas of the United States. However, it has been shown that some soils of the humid areas contain sufficient molybdenum to produce toxic forage under certain conditions (7).

The present study was made to determine the total molybdenum content of some of the more important soil series of West Virginia.

## Experimental Methods

Eighty soil samples were analyzed for their total molybdenum content. These samples represented 30 soil series and were collected from 26 counties in the State.

Soil samples were collected by staff members of the Department of Agronomy and Genetics and by soil scientists of the Soil Conservation Service. Samples were generally taken at a depth of 0-6 inches. Insofar as possible, samples were collected from areas which had received no fertilizer, lime, or farm manure during their known history. Most of the samples came from woodland, fence rows, idle fields, or untreated pastures. Descriptions of the sample sites are given in the Appendix.

[1]Unpublished Data, West Virginia University Agricultural Experiment Station, 1952.

Samples were prepared for analysis by grinding in an agate mortar to pass through 97-mesh silk bolting cloth. Duplicate analyses were made of each sample, and all results are the average of these analyses. Analyses were made by fusing the soil samples with sodium carbonate followed by determination of molybdenum using the thiocyanate-stannous chloride method. Fusion was accomplished according to the method of Robinson (6) and chemical determination following the method outlined by Prince (5).

## Results

A summary of the molybdenum content of the soils analyzed is given in Table 1. The soil grouping used here is an arbitrary one, grouping soils according to their parent material. Molybdenum content of the individual samples is given in the Appendix.

The over-all average for the soils analyzed was found to be 1.76 ppm total molybdenum.

The upland soils derived from limestone, or limestone and shale parent material, were far above average in total molybdenum content. The Hagerstown, Brooke, and Westmoreland were particularly high in total molybdenum.

The Huntington series, a bottomland soil derived from limestone influenced alluvium, was also high in total molybdenum. In general the bottomland soils strongly reflect the influence of the upland soils which supplied their parent material. The samples of the Pope series were all low in total molybdenum, as were the upland soils with which the Pope is associated. The Moshannon series, developed on alluvium principally from the Upshur series, was intermediate in molybdenum content, as was the Upshur series.

The soils derived from the tilted sandstone, siltstones, and shales of the Ridge and Valley Province of the eastern part of the State were much lower than average in total molybdenum content. As a group these soils contained less than one-half as much total molybdenum as the soils derived from limestone parent material. Almost all of the individual soils in this group were very low in total molybdenum and appeared to be highly variable in molybdenum content. This group included an Ashby channery loam from Mercer County which contained 0.42 ppm total molybdenum, the lowest of any sample analyzed.

The Berks series, because it is found in association with the limestone soils, was not grouped with the other soils developed on tilted sandstone, siltstone, and shale. In molybdenum content it was not at all like the other soils developed on the tilted formations. There were originally only two Berks samples, and those contained 1.67 and 11.70

Table 1. Molybdenum Content of West Virginia Soils ppm Total Molybdenum

| Soil Series | No. of Samples | Range | | Average |
|---|---|---|---|---|
| | | Low | High | |
| I. Well-drained, upland soils of the Limestone Valley | | | | |
| A. *From limestone* | | | | |
| Berkeley | 2 | 1.43 | 2.32 | 1.88 |
| Hagerstown | 4 | 2.27 | 3.97* | 2.91 |
| Frankstown | 1 | | | 1.52 |
| Frederick | 4 | 1.33 | 2.25 | 1.81 |
| | 11 | | | 2.20 |
| B. *From shale* | | | | |
| Berks | 6 | 1.67 | 11.70 | 4.45 |
| II. Well-drained, upland soils of the Ridge and Valley Province | | | | |
| Ashby | 4 | 0.42 | 1.59 | 1.02 |
| Belmont | 1 | | | 1.17 |
| Calvin | 3 | 0.72 | 1.39 | 1.01 |
| Lehew | 3 | 0.53 | 1.68 | 0.97 |
| Litz | 2 | 0.84 | 0.92 | 0.88 |
| Teas | 4 | 0.93 | 1.52 | 1.22 |
| Ungers | 1 | | | 0.98 |
| | 18 | | | 1.04 |
| III. Well-drained, upland soils of the Allegheny Plateau | | | | |
| A. *From limestone and shale* | | | | |
| Brooke | 3 | 2.05 | 2.64 | 2.28 |
| Westmoreland | 2 | 2.78 | 3.14 | 2.96 |
| | 5 | | | 2.56 |
| B. *From sandstone and shale* | | | | |
| Clymer | 3 | 0.97 | 1.77 | 1.36 |
| Dekalb | 4 | 0.59 | 2.40 | 1.39 |
| Gilpin | 5 | 0.95 | 2.48 | 1.74 |
| Muskingum | 3 | 1.08 | 1.39 | 1.28 |
| Upshur | 1 | | | 1.93 |
| Upshur-Gilpin | 1 | | | 1.76 |
| Upshur-Muskingum | 2 | 1.40 | 2.30 | 1.85 |
| Wellston | 2 | 0.74 | 1.07 | 0.90 |
| Wharton | 3 | 1.30 | 2.70 | 2.15 |
| | 24 | | | 1.57 |
| IV. Miscellaneous | | | | |
| A. *From alluvium* | | | | |
| Huntington | 3 | 1.76 | 3.03 | 2.45 |
| Moshannon | 2 | 1.25 | 1.60 | 1.42 |
| Pope | 3 | 0.85 | 1.50 | 1.11 |
| | 8 | | | 1.69 |
| B. *Planosols* | | | | |
| Cookport | 1 | | | 0.87 |
| Tilsit | 3 | 1.24 | 1.55 | 1.39 |
| | 4 | | | 1.26 |
| C. *Terrace soils* | | | | |
| Wheeling | 2 | 1.30 | 1.96 | 1.63 |
| Zoar | 2 | 1.30 | 2.91 | 2.10 |
| | 4 | | | 1.87 |

*Subsoil sample.

ppm molybdenum. Because of the high molybdenum content of the one sample, several additional samples were collected and analyzed. These all fell within the extremes of the original samples.

Microscopic examination of individual shale particles screened from this soil revealed small seams of a black or very dark mineral. These seams varied in thickness but most were not thick enough to be seen readily with the naked eye. Shale particles were divided into two groups, one containing a large amount of the dark mineral and designated *"high impurity,"* and one containing a small amount of the dark mineral and designated *"low impurity."* A sample of shale particles containing no detectable dark seams was also hand picked under a microscope. Duplicate determinations of the total molybdenum content of the samples were made. The "high impurity," "low impurity," and shale particles contained 18.20, 5.55, and 1.28 ppm molybdenum, respectively. The high molybdenum content of the "high impurity" sample suggests that the high molybdenum content of the Berks samples may be due, at least in part, to the presence of minerals containing concentrations of molybdenum. The brown shale particles contained less total molybdenum than any of the Berks soil samples.

# Discussion

It is impossible to state precisely where deficiencies might be found on the basis of a soil analysis for total molybdenum. Knowledge of the total molybdenum content of the soil does give a picture of the potential supply of the mineral present. On the basis of the 80 soil samples analyzed only a few areas were sufficiently low in total molybdenum that molybdenum deficiency might be expected. The Ashby, Calvin, Litz, and Lehew soils were very low in total molybdenum. However, with the possible exception of the Ashby sample from Mercer County (0.42 ppm total molybdenum), molybdenum is probably not the limiting factor for plant growth on these soils. Their low productivity is probably due to a combination of several chemical and physical properties. These soils are generally developed on steep topography from materials high in silt and generally low in essential nutrient elements. They are generally shallow and droughty. Water, lime, and major nutrient elements are all generally in low supply. Under these conditions of low productivity, molybdenum would not likely be limiting even though the supply is relatively low. However, in areas where production is increased by lime, fertilizer, and possibly irrigation, the rather low molybdenum supply might become limiting in a relatively short period of time. Lime in particular would tend to increase the availability of the native soil molybdenum bringing about a greater removal of molybedum even if no increase in yield were obtained.

The Ashby soil from Mercer County approaches very closely the 0.40 ppm suggested by Evans (4) as the point where molybdenum deficiency occurs regardless of pH. Several other soils approach the range of expected deficiency. However, in all cases, lime or some other factor is likely to be more limiting than molybdenum. In order to get a large response from adding molybdenum to an acid soil, such as has been reported in New Zealand and Australia (1,3), molybdenum *must* be more limiting than lime or other factors which might limit production. Such does not appear to be the case under West Virginia conditions. The addition of lime results in an increase in availability of a number of elements in the soil, including molybdenum. Lime also reduces the solubility, and hence the availability, of elements which may be toxic to plants. The addition of molybdenum, for all practical purposes, does not change the availability of any other element.

Soils that are low in total molybdenum and are fairly productive would be more likely to become deficient in molybdenum than the soils mentioned above. The Pope series, particularly the sandy type, represents a good example of this situation. This series was far below average in total molybdenum content but is generally considered above average in over-all productivity. Since most of the periodic alluvial deposits are eroded from soil already low in molybdenum and consist of coarse material, little molybdenum would be added from this source. Over a period of years the molybdenum supply could become reduced enough to cause a deficiency.

The Berks series provided the only samples containing such high quantities of molybdenum that toxicity to livestock might occur. Instances of molybdenum toxicity have been reported on soils containing considerably less total molybdenum than two of the Berks samples. However, the toxicities occurred on poorly- or imperfectly-drained soils with a neutral to strongly alkaline reaction. Under these conditions a large portion of the total molybdenum would exist in a water-soluble state. It is very doubtful that sufficient molybdenum would become available in the Berks soil to produce toxic forage.

## Summary and Conclusions

Eighty soil samples, representing 30 important soil series in West Virginia, were analyzed for total molybdenum.

The average molybdenum content of these soils was 1.76 ppm total molybdenum. The soils derived from limestone or limestone and shale parent material and the finer-textured soils were generally above average in total molybdenum. The coarser-textured soils and those derived from the tilted sandstones, siltstones, and shales of the Ridge and Valley

Province were below average in total molybdenum. The total molybdenum content ranged from .42 ppm in an Ashby channery loam from Mercer County to 11.70 ppm in a Berks shaly silt loam from Berkeley County.

Most of the soils analyzed contained sufficient, but not excessive, total molybdenum. The total molybdenum content was lower than would be desired in the soils of the tilted formations of the eastern half of the State, particularly the Ashby, Litz, Lehew, Ungers, and Calvin series, and in some of the coarser-textured soil types, particularly of the Dekalb, Wellston, and Pope series.

Some samples of the Berks series contained relatively high amounts of molybdenum. However, no production of toxic forage would be expected except under exceptional conditions.

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# APPENDIX A

## Description and Molybdenum Content of Individual Soil Samples

| Soil Type | Total Mo ppm | County | Site Description | Location* |
|---|---|---|---|---|
| 5 Ashby channery loam | 0.42 | Mercer | ...... | 1 mi. E. of Bluefield |
| 6 Ashby shaly silt loam | 1.59 | Pocahontas | Woodland | ...... |
| 7 Ashby shaly silt loam | 1.06 | Randolph | Woodland | 15-62 SE corner |
| 8 Ashby shaly silt loam | 1.00 | Berkeley | Old field | 90-10 |
| Belmont silt loam | 1.17 | Tucker | Meadow in rotation | 1 mi. NW of Weiss Knob |
| 20 Berkeley clay loam | 2.32 | Berkeley | Pastured woodland | Conklyn's farm |
| 20A Berkeley clay loam | 1.43 | Berkeley | ...... | 40-29 |
| 22 Berks shaly silt loam | 11.70 | Berkeley | Woodland | 43-95 3 mi. E. of Bunker Hill |
| 22A Berks shaly silt loam | 4.70 | Berkeley | Idle field | ...... |
| 22A Berks subsoil | 3.87 | Berkeley | Idle field | ...... |
| 23 Berks shaly silt loam | 1.67 | Berkeley | Woodland | AGS 41-03 S. Central |
| 23A Berks silt loam | 2.15 | Berkeley | Idle field | 1 mi. E. of Inwood |
| 23B Berks shaly silt loam | 2.69 | Berkeley | Pastured woodland | 3 mi. E. of Bunker Hill |
| 30 Brooke silty clay loam | 2.15 | Ohio | Fence row | 5-307 ⅛ mi. W. of power line |
| 30A Brooke silty clay loam | 2.64 | Ohio | Woodland | 5-307 NW corner |
| 32 Brooke | 2.05 | ...... | ...... | ...... |
| 41 Calvin silt loam | 0.91 | Greenbrier | Woodland | S. of Rt. 60 at Alta |
| 41A Calvin | 1.39 | Greenbrier | Roadbank | ...... |
| 42 Calvin silt loam | 0.72 | Tucker | Woodland | 15-46 Center |
| 55 Clymer silt loam | 1.33 | Nicholas | Fence row | DDF 36-61 |
| 56 Clymer fine sandy loam | 0.97 | Greenbrier | Woodland | S. of Rt. 60 at Alta |
| 57 Clymer silt loam | 1.77 | Upshur | Woodland | 20-50 S. Central |
| 62 Cookport silt loam | 0.87 | Raleigh | ...... | 1 mi. E. of Bluefield |
| 69 Dekalb loam | 0.59 | Raleigh | ...... | 2 mi. N. of Beaver |
| 70 Dekalb stony loam | 1.00 | Greenbrier | Woodland | CUS 4-51 |
| 71 Dekalb channery silt loam | 2.40 | Randolph | Woodland | 37-192 S. Central |
| 72 Dekalb stony silt loam | 1.56 | Preston | Woodland | AMZ 14-71 SW Central |
| 95 Frankstown silt loam | 1.52 | Greenbrier | Fence row | CMS 8-16 |
| 98 Frederick silt loam | 1.33 | Mercer | ...... | 3 mi. E. of Bluefield |

*Numbers refer to S.C.S. aerial photo numbers

# APPENDIX A Continued

| Soil Type | Total Mo ppm | County | Site Description | Location* |
|---|---|---|---|---|
| 99 Frederick sherty silt loam | 2.25 | Monroe | Roadbank | CMS 10-24-Sinks Grove |
| 100 Frederick silt loam | 1.67 | Berkeley | Woodland | ...... |
| 101 Frederick stony silt loam | 1.98 | Berkeley | Unpastured woodland | AGS 41-24 E. Central |
| 102 Gilpin silt loam | 1.73 | Marshall | Unfertilized pasture | ...... |
| 103 Gilpin silt loam | 1.40 | Nicholas | Woodland, oak, and hickory | DDF 22-55 |
| 104 Gilpin silt loam | 0.95 | Raleigh | ...... | Piney View |
| 105 Gilpin | 2.48 | Upshur | Woodland | DDF 14-45 |
| 106 Gilpin silt loam | 2.14 | Monongalia | Woodland | AMZ 14-49 S. Central |
| 116 Hagerstown silt loam | 2.27 | Pocahontas | Roadbank | 1 mi. E. of Hillsboro |
| 117 Hagerstown silt loam | 2.30 | Jefferson | Fence row | 4 mi. S. of Charles Town |
| 118 Hagerstown stony silt loam | 3.12 | Berkeley | Woodland | AGS 40-24 SW corner |
| 118 Hagerstown subsoil | 3.97 | Berkeley | Woodland | AGS 40-24 SW corner |
| 123 Huntington silt loam | 2.56 | Marshall | Idle land | 1-47 Center |
| 125 Huntington silt loam | 1.76 | Mason | Fence row | AMF 64-38 |
| 801 Huntington silt loam | 3.03 | Berkeley | Untreated pasture | AGS 32-123 |
| 143 Lehew loam | 1.68 | Hampshire | Fence row | Rt. 259 1 mi. S. of Lehew |
| 143A Lehew channery fine sandy loam | 0.53 | Hampshire | Woodland | Rt. 50 AGU 73-69 |
| 143B Lehew loam | 0.69 | Hampshire | Fence row | AGU 93-58 N. Central |
| 148 Litz shaly silt loam | 0.92 | Mercer | ...... | Camp Creek |
| 149 Litz shaly silt loam | 0.84 | Monroe | Bluegrass yard | CMS 11-3 2 mi. W. of Union |
| 169 Moshannon silt loam | 1.60 | Wirt | Bluegrass, ironweed | 221 |
| 170 Moshannon silt loam | 1.25 | Jackson | Creekbank | AMC 60-74 |
| 174 Muskingum silt loam | 1.39 | Kanawha | Woodland | DDF 35-44 |
| 175 Muskingum silt loam | 1.08 | Boone | Woodland-good condition | 14-66 |
| 176 Muskingum silt loam | 1.36 | Raleigh | ...... | 3 mi. S. of Arnett |
| 186 Pope sandy loam | 0.85 | Lincoln | Idle cropland | 68-63 Center |
| 187 Pope sandy loam | 0.99 | Upshur | Untreated meadow | 20-43 Center |
| 188 Pope gravelly silt loam | 1.50 | Preston | Woodland | AMZ 14-169 E. Central |
| 208 Teas silt loam | 1.29 | Summers | ...... | 3 mi. W. of Hinton on Rt. 3 |
| 210 Teas silt loam | 0.93 | Randolph | Woodland | 18-100 SE corner |
| 210 Teas subsoil | 1.15 | Randolph | Woodland | 18-100 SE corner |

*Numbers refer to S.C.S. aerial photo numbers

# APPENDIX A Continued

| Soil Type | Total Mo PPM | County | Site Description | Location* |
|---|---|---|---|---|
| 211 Teas silt loam | 1.52 | Preston | Untreated pasture | AMZ 12-161 SE Central |
| 212 Tilsit silt loam | 1.55 | Mason | Fence row | AMF 84-15 |
| 213 Tilsit silt loam | 1.40 | Wayne | Old Field | 85-22 |
| 214 Tilsit silt loam | 1.24 | Mercer | ...... | 2 mi. E. of Speedway |
| Ungers loam | 0.98 | Tucker | Untreated pasture | ...... |
| 222 Upshur clay loam | 1.93 | Jackson | Abandoned Field | AMC 62-42 |
| 154 Upshur-Gilpin silty clay | 1.76 | Wirt | Untreated pasture | 245 |
| 155 Upshur-Muskingum silty clay | 1.40 | Jackson | Woodland | AMC 62-43 100′ S. of Rt. 33 |
| 156 Upshur-Muskingum clay | 2.30 | Wayne | Worn out cropland | 47-14 W. Central |
| 233 Wellston fine sandy loam | 0.74 | Wayne | Honeysuckle patch | 47-14 E. Central |
| Wellston subsoil | 1.07 | Wayne | Honeysuckle patch | 47-14 E. Central |
| 235 Westmoreland silt loam | 3.14 | Ohio | Abandoned orchard | 6-486 NW Corner |
| 237 Westmoreland silt loam | 2.78 | Marion | Idle land | 1 mi. SW of Kilarn |
| 239 Wharton silt loam | 2.44 | Marshall | Brushy pasture field | 1-49 near center |
| 240 Wharton silt loam | 1.30 | Nicholas | Old fence row | DDF 22-53 |
| 241 Wharton silt loam | 2.70 | Preston | Fence row | AMZ 14-32 Center |
| 243 Wheeling silt loam | 1.96 | Wetzel | Cemetery | 29-77 SW. |
| 245 Wheeling silt loam | 1.30 | Mason | Fence row | AMF 83-81 100′ E. of Rt. 62 |
| 251 Zoar | 1.30 | Wirt | ...... | 205 |
| 253 Zoar silt loam | 2.91 | Nicholas | Fence row | ½ mi. S. of Muddelty |

*Numbers refer to S.C.S. aerial photo numbers